Expectations vs. Experience: Training Lessons Based Upon Miners' Difficulties When Using Emergency Breathing Apparatus

Charles Vaught, Launa Mallett, Michael Brnich, Jr., and Robert Peters

National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory
P.O. Box 18070, Pittsburgh, Pennsylvania 15236, USA
Email: cav9@cdc.gov

ABSTRACT

Interviews of 48 miners who escaped underground coal mine fires revealed that none of them had ever, before that incident, worn their self-contained self-rescuer (SCSR) either in training or in a real emergency. Consequently, they were ill-prepared to use this emergency breathing apparatus. One persistent problem stemmed from the fact that miners had no notion of breathing resistance, nor of the fact that it would get more difficult to breathe the longer they wore their device. As a result, many of those who were interviewed had simply removed their mouthpieces and breathed ambient air. This is obviously behavior that should be trained out of the workforce. Unfortunately, because of high costs and difficult logistics, miner training is unlikely to ever include donning and wearing an apparatus on a regular basis.

In order to give workers a better idea of what to expect from their devices, therefore, the National Institute for Occupational Safety and Health researchers developed a tabletop (paper and pencil) simulation based upon actual predicaments evacuees had reported encountering. The simulation is designed to emphasize important points related to donning and wearing a self-contained self-rescuer in a mine fire escape, and, by doing so, to bring miners' expectations more in line with what their actual experiences would be. The simulation was field tested in six training classes at three different mining operations. In all, 99 individuals were involved in completing the exercise and rating its properties. In their ratings 88% of the respondents indicated they thought the scenario could definitely happen in real life, and over 80% agreed they had learned something new. From the field test data it was concluded that the simulation had authenticity and potential value as a teaching tool. The simulation was therefore used in a pre-test/post-test control group experiment to determine whether it led to improvements in miners' scores on a true-false test of their SCSR's functional capabilities and proper usage. Eighty-three miners were included in this part of the study. As expected, miners who had participated in the training exercise scored significantly higher on their post-test than miners who had not.

Keywords: emergency breathing apparatus, self-contained self rescuers, miners, tabletop simulation, training

INTRODUCTION

When a coal mine fire occurs in the United States, the self-rescue protocol for miners requires them to evacuate the workings, if possible. Only as a last resort are the workers to try to barricade. Given that a miner would have to travel through an atmosphere that could quickly become toxic or oxygen deficient, escape might be impossible unless the individual was able to isolate his or her lungs from ambient conditions.

The air current sweeps smoke, dust, and liberated gasses away from the faces and into the mine's "return" air courses for its journey to the return air shaft, at which point it is exhausted into the outside atmosphere.

Ventilation, the same system that makes mining possible in the first place, can render an escape virtually impossible during a fire. Not only is the ventilation arrangement likely to bring a continuous flow of oxygen to the fire site, feeding the fire, it may, if it becomes compromised, carry heavy concentrations of toxic smoke and gases into the working sections and into miners' escapeways. Workers are taught that escapeways aren't supposed to be contaminated, because the US Code of Federal Regulations requires underground operations to maintain separate and distinct passages, ventilated by fresh intake air, extending from each working section to the outside. In truth, either direct human action such as a worker's failure to close an access door, or environmental factors such as the deterioration of a stopping due to heat or pressure, can turn an escapeway into a horizontal chimney. The confusion caused by such an unanticipated occurrence then becomes a compounding factor in an already problematic event.

In order to escape through mine entries that may be smoke-filled, oxygen deficient, and contaminated by carbon monoxide, miners have to be able to do two things: First, they must don their emergency breathing apparatus correctly in order to isolate their lungs from the ambient atmosphere. Second, they must wear and use their device for an extended period of time as they attempt to find their way out of the mine. It seems apparent that the greater one's understanding of the situation, and the better grasp he or she has of those factors that may arise as predicaments, the better equipped he or she will be to deal with the emergency. Since real world events are rare and full scale mock drills are very expensive - and hence also rare - expectations have to be forged in a different way. Several organizations that must maintain a high level of preparedness for non routine occurrences have used simulations in their training programs (Halff, et al., 1986; Lacefield and Cole, 1986).

USING A SIMULATION FOR EXPECTATIONS TRAINING

The authors have long been involved in the construction and field testing of paper-and-pencil ("tabletop") exercises based upon case studies of actual mine fire escapes. Unlike the case studies they are based on, however, these simulations do not present the reader with a seamless narrative about the emergency and lessons learned from its resolution. Rather, they require active information seeking and problem solving with no foreknowledge about how a particular course of action might turn out (until it is chosen). This uncertainty, along with the predicaments engendered by having to make critical choices based on incomplete information, have proven effective in the use of simulations to transfer some of the cognitive skills miners would need in order to cope with an actual emergency (Cole et al., 1998).

To date, exercises developed by the authors have focused on the two large domains of emergency decision making and first aid skills. Because of workers' reported problems using their SCSRs (Vaught et al., 2000), however, it was decided to design a simulation entitled "I Can't Get Enough Air." This simulation is centered much more upon the mechanics of SCSR usage than upon escape behavior itself. The following subsections describe the exercise origin and structure.

Exercise background: As part of their investigations regarding worker responses to mine fires, NIOSH researchers interviewed 48 miners about their escape experiences. Accounts given by these workers have been analyzed regarding how SCSRs were used during their escapes.

In general, workers reported several problems that indicate they weren't adept at donning their devices. The problems included difficulty locating the oxygen lever on compressed oxygen SCSRs and leaving the mouthpiece plug in place when inserting the mouthpiece. Slightly more than 40% of the miners who donned compressed oxygen apparatus said that they blew into the SCSR (to inflate the breathing bag) on the first breath. This is not only an incorrect action, but also potentially dangerous. Many workers reported difficulty adjusting the neck and waist straps. In sum, more than 40% of all the interviewees recounted having trouble of one sort or another when they donned their SCSR. Of these, about one half indicated that they needed help from a buddy to get the apparatus on.

The responses are marked (using a developing pen) on a corresponding answer sheet that has been printed in invisible ink. As each chosen response is marked, a message appears that contains two types of information. First, the trainee is informed whether or not the choice is "correct." Then, whether the choice is correct or incorrect, further information is given related to his or her decision. The first problem frame is shown in Figure 1. The trainee, after studying the question and its five alternatives, will turn to the answer sheet (Figure 2) and highlight the space between the numbered brackets of his or her choice. The response(s) being highlighted will then appear, while the rest remain invisible. As Figure 2 suggests, the consequence of selecting any alternative (or the consequence of not selecting a particular alternative) becomes known only after the decision has been made. In this manner, miners being trained will work through a series of predicaments, making wise or unwise choices at each juncture of the problem, until there is a final resolution.

Question A

You and your crew go through the mandoor at #31 crosscut into the belt entry. The air is clear and you travel about six crosscuts, at which point you find light smoke. What should you do now? (Select as MANY as you think are correct.)

1. Watch the smoke for a while to see if it subsides.
2. Tell everyone to don their SCSR now.
3. Tell everyone to open their SCSR and loop it around their neck, but not to activate the apparatus.
4. Take your crew, lead them back to the section, and go out the return escapeway.
5. Check the time.

When you have made your selection(s) do the next question.

Figure 1. The first frame of the "I Can't Get Enough Air" simulation.

Question A (Select as MANY as you think are correct.)

1. [This can be dangerous. You need to act now.]

2. [Correct! You need to get your SCSR on now.]

3. [Although you find light smoke in the belt entry, you don't know what toxic gasses are]
[in the air. You need to use your SCSR now.]

4. [You have already come 15 crosscuts outby the faces. Going back to the section to]
[get into the return escapeway will waste time.]

5. [Correct! Since you will be in smoke, you will need to have some time reference]

Figure 2. Responses for the first frame of the "I Can't Get Enough Air" simulation.

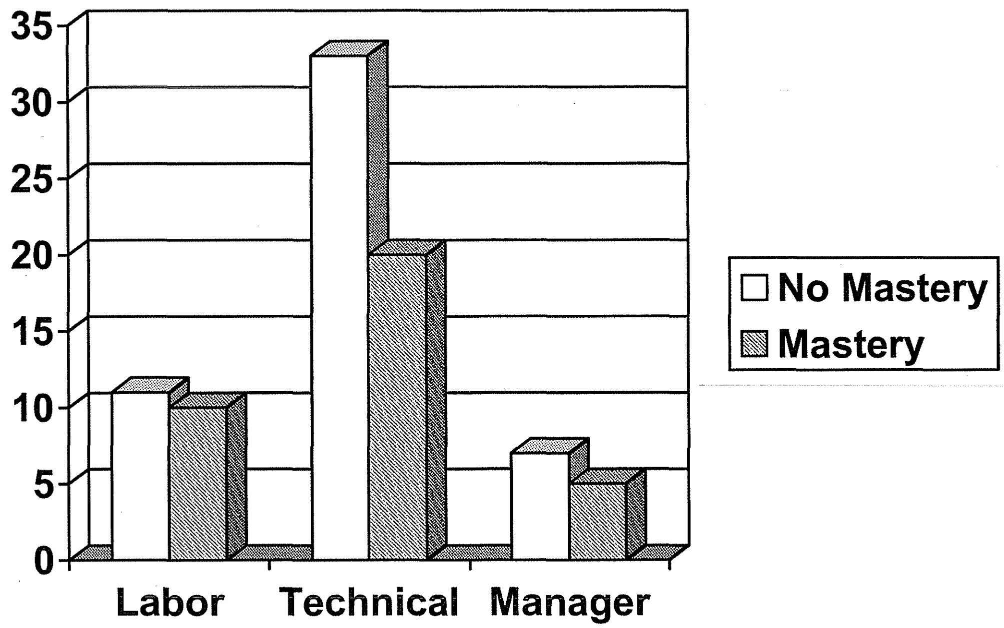

Figure 3. Level of mastery by job category.

Table I. Chi-Square Results for Level of Mastery by Job Category and Mine Rescue Training

Statistic	Job Category			Mine Rescue Training		
	Value	Degree of Freedom	Asymptotic Significance level (2-sided)	Value	Degree of Freedom	Asymptotic Significance level (2-sided)
Pearson Chi-Square	0.614	2	0.736	4.787	1	0.029
Likelihood Ratio	0.610	2	0.737	4.861	1	0.027
Linear-by-Linear Association	0.228	1	0.633	4.733	1	0.030
N of Valid Cases	86			89		

It was when the sample was broken out by whether or not the respondents had ever had mine rescue training or experience that clear differences emerged in terms of performance on the simulation (see Figure 4). Here, even though the apparatuses are different and the protocols are very dissimilar, expertise in the mine rescue domain seems to have helped trainees in dealing with some of the predicaments from the self-rescue problem. The chi-square results for this breakdown (Table I) indicate a significant (.029) difference between the two categories.

Table II. Miners' Rating of Exercise Validity and Quality (Frequency %)

Statistic	Likert Rating Scale				Mean (n=93)	SD
	Definitely yes			Definitely no		
	4	3	2	1		
Exercise is realistic and authentic	88.2	9.7	2.2	0.0	3.86	0.41
Helped me remember important things	64.5	34.4	1.1	0.0	3.63	0.51
Learned something new	46.7	37.0	16.3	0.0	3.30	0.74
Exercise too long	1.1	4.3	14.0	80.6	1.26	0.59
Liked working exercise	68.8	29.0	2.2	0.0	3.67	0.52
Instructor's directions clear	88.2	11.8	0.0	0.0	3.88	0.33
Written directions clear	74.2	23.7	2.2	0.0	3.72	0.50
Graphics easy to understand	68.8	26.9	4.3	0.0	3.65	0.56
Scoring easy to understand	67.7	23.7	6.5	2.2	3.57	0.71
Exercise easy to read	83.9	16.1	0.0	0.0	3.84	0.37

Does participation in the training exercise increase miners' knowledge of SCSRs?

Two versions of a 25 item true-false test were developed to assess trainees' knowledge of their SCSR's functional capabilities and proper procedures for use. Although the 25 questions were exactly the same in the two versions of the true-false tests, the order in which the questions were presented was different. The "I Can't Get Enough Air" training exercise was administered to two groups of experienced coal miners as part of their annual mine safety and health training class. One group served as the experimental group. They were given the first version of the true-false test, then they participated in the "I Can't Get Enough Air" training exercise, then they completed the second version of the true-false test. The second group of miners served as the control group. They were given version 1 of the true-false test, then after a two minute break, they took version 2 of the true-false test. Finally, they participated in the "I Can't Get Enough Air" training exercise.

The hypotheses are as follows: 1) The mean of the experimental group's version 2 (post-training) scores will be significantly higher than the mean of their version 1 (pre-training) scores; and 2) the mean gain in the experimental group's scores will be significantly higher than the mean gain in the control group's scores.

Table III shows the means and standard deviations for the experimental and control groups' scores on versions 1 and 2 of the test. Using a paired one-tailed t test, it was found that the mean of the experimental group's post-training scores was significantly higher than the mean of their pre-training scores ($t = 4.626$, $p < .001$). This strongly supports the first hypothesis.

REFERENCES

Brnich MJ, Vaught C, & Calhoun R. (1999) I can't get enough air! Proper self-contained self-rescuer usage. Washington, D.C.: U.S. Department of Health and Human Services.

Cole H, Vaught C, Wiehagen WJ, Haley JV, & Brnich MJ, Jr. (1998) Decision making during a simulated mine fire escape. IEEE Transactions on Engineering Management, 45(2), 153-162.

Cole HP, Moss J, Gohs FX, Lacefield WE, Barfield BJ, & Blythe DK. (1984) Measuring learning in continuing education for engineers and scientists. Phoenix: Oryx Press.

Flathers GW, Jr., Giffin WC, & Rockwell TH. (1982) A study of decision making behavior of pilots deviating from a planned flight. Aviation, Space, and Environmental Medicine, 53(10), 958-963.

Fotta B, Bockosh G, (2000) The aging workforce: An emerging issue in the mining industry. In Proceedings of the 31st Annual Mining Safety, Health and Research Conference. Virginia Tech, August. Blacksburg, VA.

Giffin WC, & Rockwell TH. (1984) Computer-aided testing of pilot response to critical in-flight events. Human Factors, 26(5), 579-581.

Halff HM, Holland JD, & Hutchins EL. (1986) Cognitive science and military training. American Psychologist, 41(10), 1131-1139.

Kowalski KM, Vaught C, Mallett L, & Brnich MJ. (1997) Worker responses to realistic evacuation training. In: Proceedings of The International Emergency Management and Engineering Society Conference (TIEMES '97), June 10-13, 1997, pp. 52-56.

Lacefield WE, & Cole HP. (1986) Principles and techniques for evaluating continuing education programs. The Military Engineer, 78(511), 594-600.

Schmidt RA. (1988) Motor control and learning: A behavioral emphasis. Champaign, IL: Human Kinetics Publishers, Inc.

Vaught C, Brnich MJ, Jr., Mallett LG, Cole HP, Wiehagen WJ, Conti RS, Kowalski KM, & Litton CD. (2000) Behavioral and organizational dimensions of underground mine fires. Washington, D.C.: U.S. Department of Health and Human Services, NIOSH IC 9450.

Vaught C, Brnich MJ Jr., Wiehagen WJ, Cole H.P, & Kellner HJ. (1993) An overview of research on self-contained self-rescuer training. Washington, D.C.: United States Department of the Interior, Bureau of Mines Bulletin 695.

Vaught C, Wiehagen WJ, & Brnich MJ Jr. (1991) Self-contained self-rescuer donning proficiency at eight eastern underground coal mines. Washington, D.C.: United States Department of the Interior, Bureau of Mines Report of Investigation 9383.